Environmental impacts of different stormwater management systems

Brudler, Sarah

Published in:
EVA : Erfaringsudveksling i vandmiljøteknikken

Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Brudler, S. (2019). Environmental impacts of different stormwater management systems. *EVA : Erfaringsudveksling i vandmiljøteknikken*, *32*(2), 18-21.

Environmental impacts of different stormwater management systems

Af: Sarah Brudler,
PhD, Specialist i miljø og bæredygtighed,
VandCenter Syd as

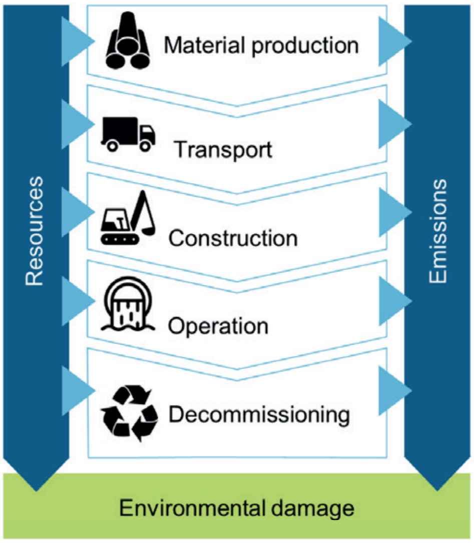

Figure 1
Life cycle of stormwater management systems (material generation, transport, construction, operation, decommissioning) with inputs (resources) and outputs (emissions) leading to environmental damage.

To design sustainable systems to manage stormwater in the future, economic assessments are not sufficient. Life cycle assessment allows to quantify and compare and the environmental impacts of stormwater management systems. When used systematically in the planning process, it can highlight options to minimize damage to the environment.

Stormwater management (SWM) systems utilizing green infrastructure (GI, Danish: LAR) provide additional benefits for humans and the environment compared to traditional, subsurface systems. However, both GI and traditional SWM systems cause environmental damage caused by resource requirements and emissions to the environment throughout their life cycle. In contrast to economic costs, these environmental impacts are rarely assessed systematically in the decision-making process. Using life cycle assessment (LCA), the environmental damage from implementing, operating and decommissioning SWM systems can be quantified **(Figure 1)**.[1] The environmental damage is expressed as damage to areas of protection that represent components of the environment of direct value to human society: resource availability (expressed as surplus extra cost for future resource extraction) and ecosystems (expressed as species loss).[5]

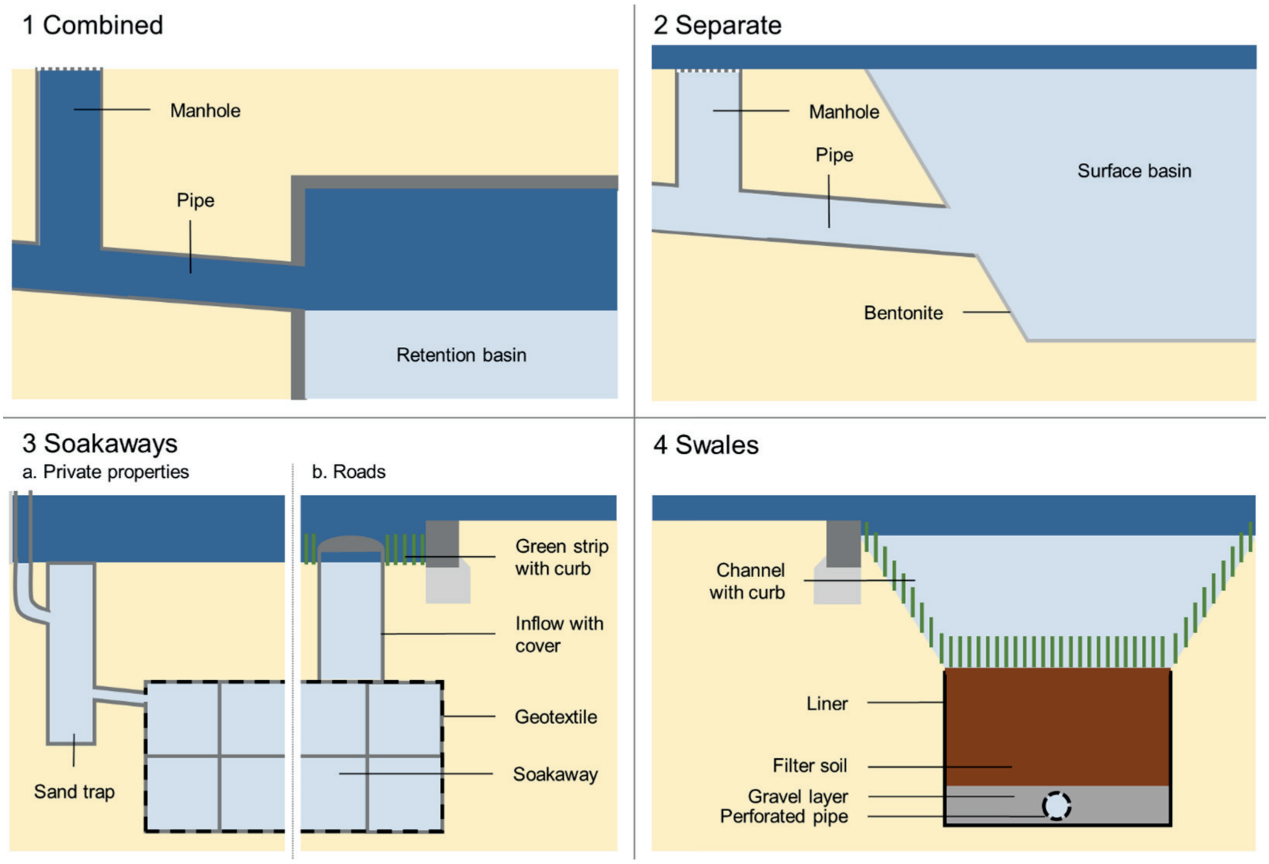

Figure 2
Schematic sketches of the elements in the four different stormwater management systems. The water level during an event with a return period of five (ten) years is illustrated in light (dark) blue.[3]

This allows to

- **compare systems to each other and identify the environmentally preferable solution when planning SWM;**

- **identify hotspots, i.e. elements and processes of SWM that cause significant environmental damage that can potentially can be minimized.**

As an example, we used LCA to assess the environmental damage of four different SWM systems for the 260ha large Skibhus catchment in Odense: two subsurface systems (one combined, one separate), and two separate GI based systems (one infiltrating stormwater in soakaways, one discharging it in swales) **(Figure 2)**. The systems were designed to comply with existing flood safety standards, i.e. the combined system was designed for events with a ten year return period, while the separate systems were designed for five year events.[2]

We first compiled all necessary material production, construction, operation and decommissioning processes of the different systems in an infrastructure inventory based on documentation of existing and planned systems, expert interviews and guidelines.[3] Furthermore, we calculated average concentrations of key pollutants in stormwater and tracked their flow through the different systems to quantify point source emissions to receiving water bodies.[4] Using life cycle impact assessment, we then quantified the resulting environmental damage from both the infrastructure related processes and discharges of polluted stormwater for each system.

The combined system causes the highest damage to resource availability (8775 USD/yr) mainly caused by the production of concrete for pipes, continuous electricity consumption for wastewater treatment and filling of pipes at the end of life. It is followed by the separate subsurface systems, which requires smaller pipes due to the lower flood safety level. Both GI based systems save resource costs (-3706 to -5227 USD/yr), which is due to avoided road renewal where green areas replace existing roads **(Figure 3a)**.[3]

Regarding ecosystem damage, a most and least favorable system can not be identified as easily. The performance of the systems is very similar, with the combined system causing the highest (0.0014 species/yr) and soakaways causing the lowest damage (0.0010 species/yr) **(Figure 3b)**. A large fraction of the damage is caused by discharges of polluted stormwater (36 – 88%) and not the infrastructure itself.

To assess the uncertainty of these results, we varied different key assumptions regarding material choices, operation and decommissioning processes and design for each system and calculated the resulting environmental damage. The changes in results were significant, partly even affecting the conclusions regarding the worst and best performing system (Figure 3). However, this uncertainty is not caused by the methodological approach, but rather by the variety of possible choices within each of the selected approaches. It highlights which parameters have to be considered to optimize the environmental sustainability of SWM systems.

Looking at resource availability damage, two parameters can be identified as hotspots. Firstly, the use of concrete, plastic and steel should be limited as it requires significant resources. Recycling of plastic used for pipes, soakaways and geotextiles at the end of life is crucial. If it is incinerated instead, soakaways become the least sustainable alternative. Secondly, the resource availability damage of combined systems can be decreased by up to 18% if renewable energy sources are used for electricity consumption required for wastewater treatment.

Ecosystem damage is most sensitive to changes in the removal efficiency of the single elements in each system. This highlights the potential to significantly reduce damage (up to -82%) by optimizing the removal efficiency already in the design phase, for example by using filter soil designed to remove metals or adding a forebay to surface basins. Furthermore, continuous maintenance is required to ensure consistent removal over time. An alternative approach to limiting ecosystem damage is preventing pollution at the source, i.e. limiting harmful substances in buildings and vehicles that are taken up by stormwater.[3]

Extensive data collection and an in-depth methodological understanding is required to carry out a detailed LCA. In the complex planning process of SWM, where decisions have to be made based on limited information, this is not a realistic option. At the same time, existing tools for evaluating environmental sustainability often provide limited or qualitative information. To close this gap, we are developing a simplified LCA based tool to quantify the sustainability of SWM systems at an early planning stage and without prior knowledge of LCA. 30 different elements can be selected, specified and combined by the user to describe the physical infrastructure and flow paths of one or more SWM systems. The tool then provides detailed and comparative results highlighting environmental hotspots. When used systematically in the planning process, this enables optimizing of the sustainability of future SWM systems.

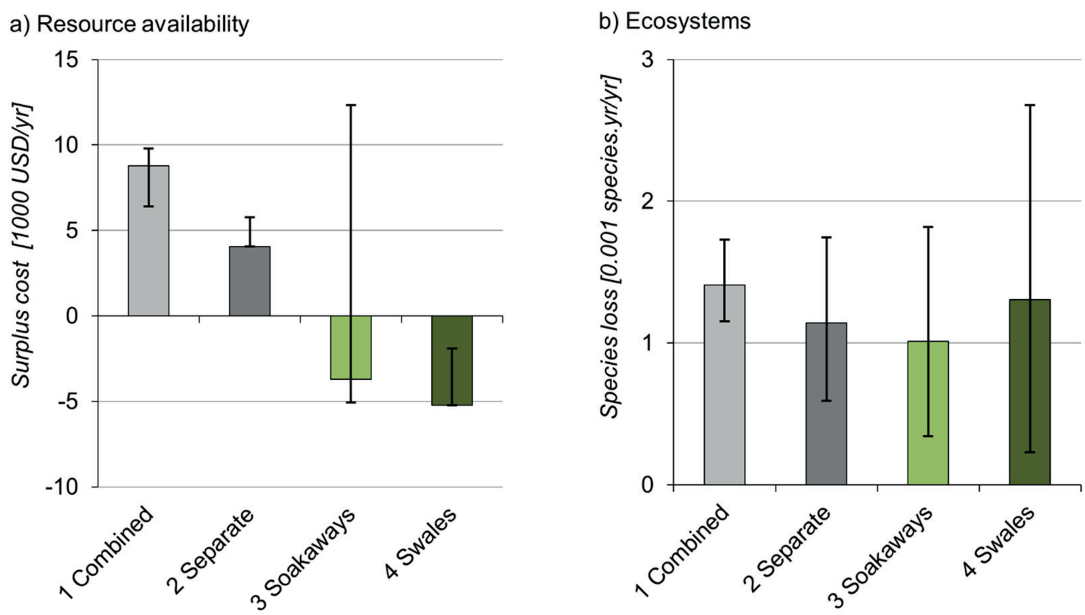

Figure 3
Damage to a) resource availability, b) ecosystems, caused by four different systems managing stormwater according to Danish flood safety standards in a catchment area of 260ha, over 25 years. Negative values indicate prevented damage. Error bars illustrate the damage for a worst and best case for each system of all tested scenarios varying both infrastructure processes and point source emissions.[3]

Acknowledgements

The presented method and results were developed in an industrial PhD project carried out at Vandcenter Syd and the Technical University of Denmark with support from Aarhus Vand, HOFOR and the Innovation Fund Denmark. Martin Rygaard, Karsten Arnbjerg-Nielsen, Michael Hauschild and Christian Ammitsøe contributed substantially to the project.

References

1. Brudler, S., Arnbjerg-Nielsen, K., Hauschild, M. Z. & Rygaard, M. Life cycle assessment of stormwater management in the context of climate change adaptation. Water Res. **106**, 394–404 (2016).

2. IDA Spildevandskomiteen. Funktionspraksis for afløbssystemer under regn. Skrift nr. 27. (2005).

3. Brudler, S. et al. Life cycle assessment of point source emissions and infrastructure impacts of four types of urban stormwater systems (submitted). Water Res. (2019).

4. Brudler, S. et al. Pollution levels of stormwater discharges and resulting environmental impacts (submitted). (2019).

5. UNEP/SETAC. Life Cycle approaches: The road from analysis to practice. (2005).